MOTOROLA
SEMICONDUCTOR
APPLICATION NOTE

AN1028

35/50 Watt Broadband (160–240 MHz) Push-Pull TV Amplifier Band III

This note describes the performance of a broadband ultra linear push pull amplifier designed for service in band III TV transposers and transmitters.

Devices used : two TPV 375.

Basic amplifier specifications :

IMD (1) = — 51 dB	at	P_0 = 35 W	P_{gain}	= 10 dB
IMD (1) = — 48 dB	at	P_0 = 50 W	input VSWR	: < 1.6
V_{ce} = 28 volts ;		Total = 4.4 A	output VSWR	: < 1.5

(1) vision carrier — 8 dB, sound carrier — 7 dB, sideband signal — 16 dB.

General design Consideration

The principal aims were :

— employ a relatively simple solution permitting us to obtain the optimal performances from TWO TPV 375.

— simplify the design and reduce the cost.

The main consideration was to obtain the maximum output power with the best IMD over the band. To obtain this requirement the output match and losses must be the best possible in all the band.

The second consideration was to obtain the maximum gain by reducing the input matching circuit losses to a minimum.

These factors led us to choose matching circuits using quarter-wavelength transformers at the input and output which permit us to :

— reduce the load and source impedances to low values with low losses

— couple two transistors in a push pull configuration.

Because the output and input transistor impedances are in series, due to the push-pull configuration, the required transformation ratio is one half of that required for a single ended stage.

The first approach for the circuit calculation was made from the input and output impedances given in the TPV375 data sheet and matched to the proper impedance levels using a Smith Chart. The element values were then optimized with the aid of «COMPACT» program.

Amplifier Design

The basic block diagram for the amplifier is shown in Figure 1 and the circuit schematic is shown in Figure 2.

The input and output circuits are each composed of two networks : a quarter-wavelength transformer-balun and a matching network.

The quarter-wavelength transformer impedances have been chosen to be easily built using microstrip technology.

Input circuit

The input circuit is shown in Figure 3 and the input impedances are shown in Smith Chart 1.

The low transistor input impedances are transformed into higher impedances near the real axis by Capacitors FF.

The (EE, DD) series elements and (CC, BB) parallel elements collapse the amplifier input impedances around 8,5 Ω.

Since the devices can be considered in series at this point the impedance is doubled to 17 Ω. The quarter-wavelength transformer balun (AA) completes the match to 50 Ω.

The transformation ratio is 2.8 : 1.

The maximum theoritical input VSWR is 1.80 : 1 and the maximum experimental VSWR is 1.60 : 1.

Output circuit

The output circuit is shown in Figure 4 and the output impedances on Smith Chart. II. Since the output impedances are higher than the input impedances, the output matching network is simpler and the quarter-wavelength transformer ratio is lower.

The inductors aid the matching but primarily provide for good stability at the low frequencies, and are used for collector bias. The output quarter-wave-length transformer ratio is 1.6 : 1.

The maximum theoretical VSWR is 1.16:1 and the maximum experimental VSWR is 1.44:1.

Amplifier Performances

— IMD versus output power : Figure 5

— Input and output return loss and VSWR = Figure 6

— Gain versus frequency : see Figure 7

— 1 dB gain point compression : 70 W

— Bias conditions : V_{ce} = 28 V ; Total = 4.4 A.

Technology and layout considerations

The epoxy-Glass 1/16 inch (ε_r = 4.1) is used as board material except for the input and ouput transformers. The glass - Teflon 1/50 inch (ε_r = 2.55) is used for the transformers (see the details Figure 8).

We have considered for a microstrip line that after W (Width) from the conductor strip edge the fields are negligible and we can size the ground conductor to be 3 W without perturbing the propagation. This kind of transformer has the following characteristics :

— We can have any impedance values within realizable min-max limits.

— The vertical dimensions are small and the mechanical realibility is good.

— Good repeatibility.

The bias circuits are included with RF circuits in order to give a compact amplifier : Figures 10 and 11 show the layouts and the Figure 12 the physical layout of the push-pull amplifier.

Combined pairs of push-pull Amplifiers

— In general several push-pull amplifiers are used for the final stage of the TV transmitter amplifiers.

They can be combined by pair with quadrature combiners (see block diagram Figure 9).

The advantage of using this kind of coupler is that the input and output VSWR become good (> 20 dB rtn. loss) in comparison with the relatively high original VSWR of the push-pull amplifier.

General Conclusions

— Pushpull techniques simplify the required circuitry and associated losses.

— The problems associated with 3 dB hybrids in cascade — insertion loss and imbalance — when four devices in parallel are required are minimized.

— With additional effort both the input and output VSWR could be improved to 1.2 : 1.

— Good repeatability in production without variable components being required.

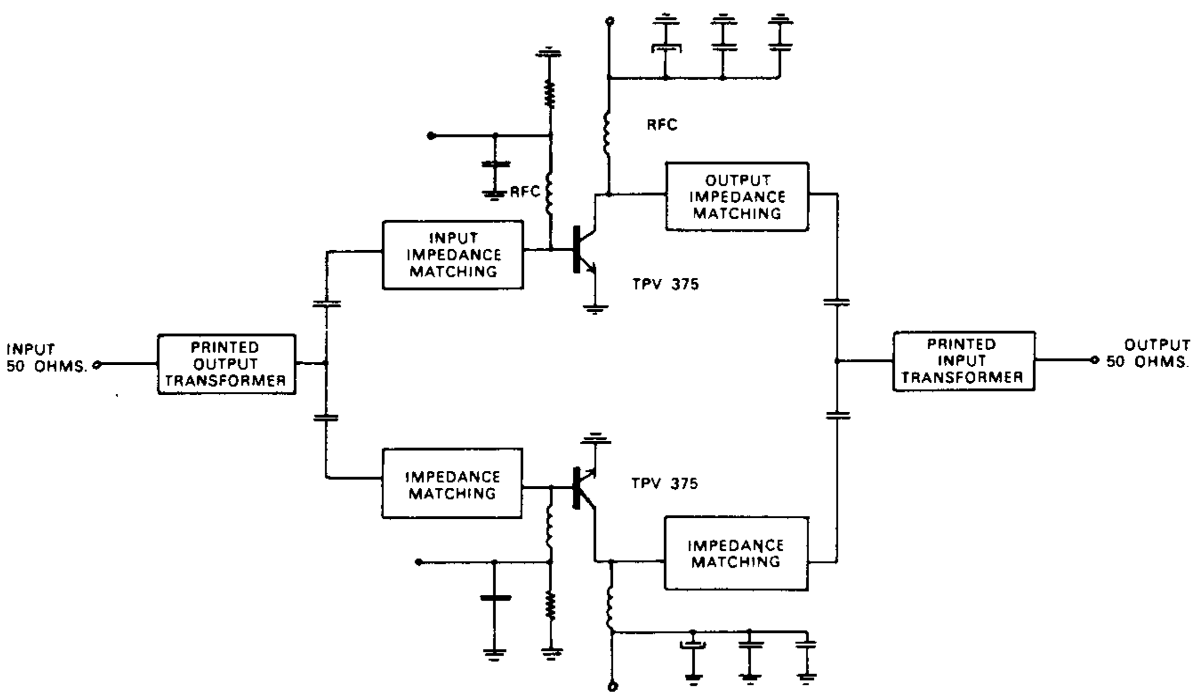


Figure 1. Push-Pull Circuit

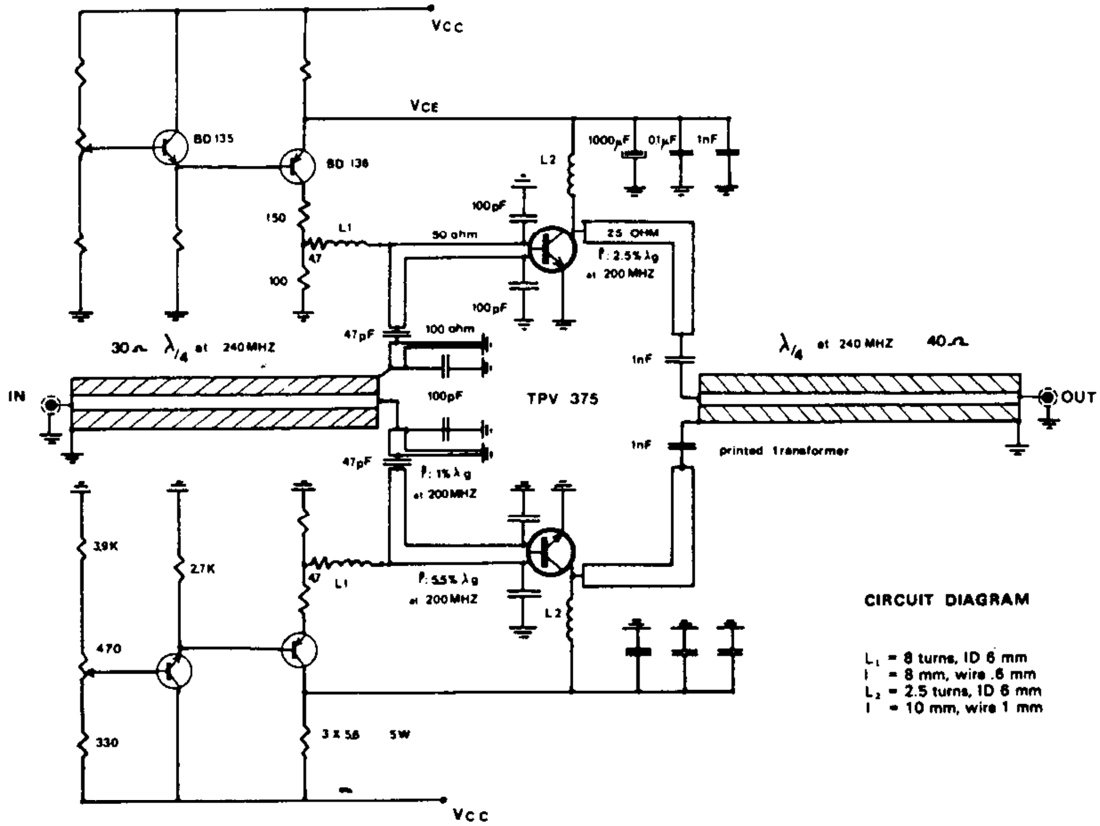
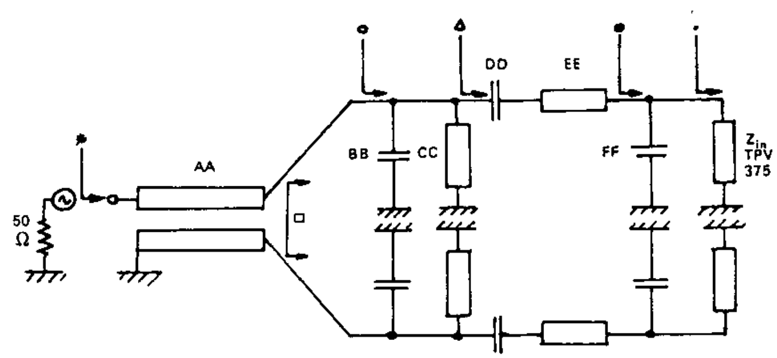


Figure 2. Circuit Diagram

On the smith chart the impedances are represented by :



	AA		BB	CC		DD	EE		FF
	Z_0 (Ω)	L* (mm)	(pF)	Z_0 (Ω)	L* (mm)	(pF)	Z_0 (Ω)	L* (mm)	(pF)
Calc. value	30	313	139	100	11.3	47	50	80.8	238
Empirical value	30	313	100	100	15.0	47	50	82.5	200

* L is given for $\varepsilon_r = 1$

Figure 3. Input Circuit

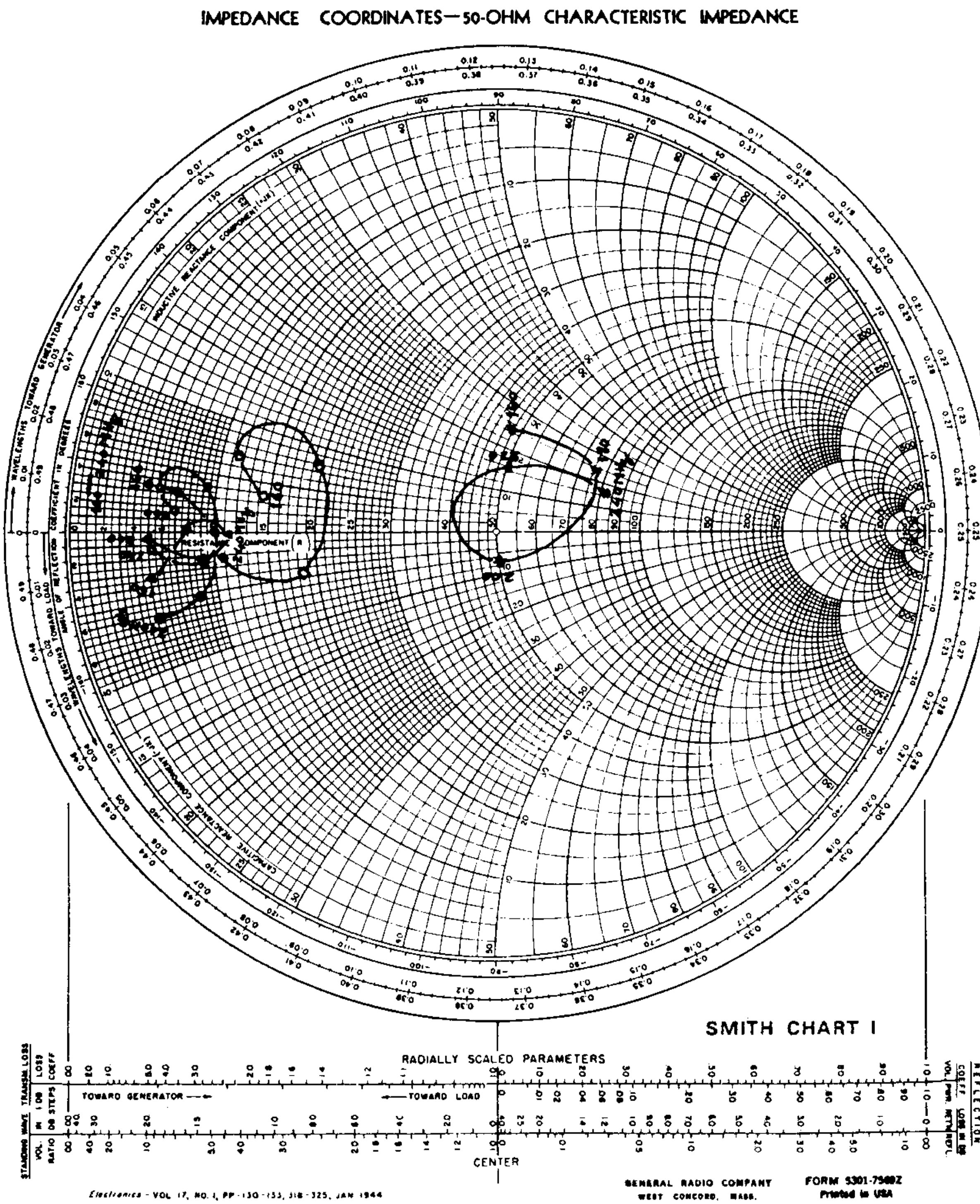


Figure 4A. Input Circuit

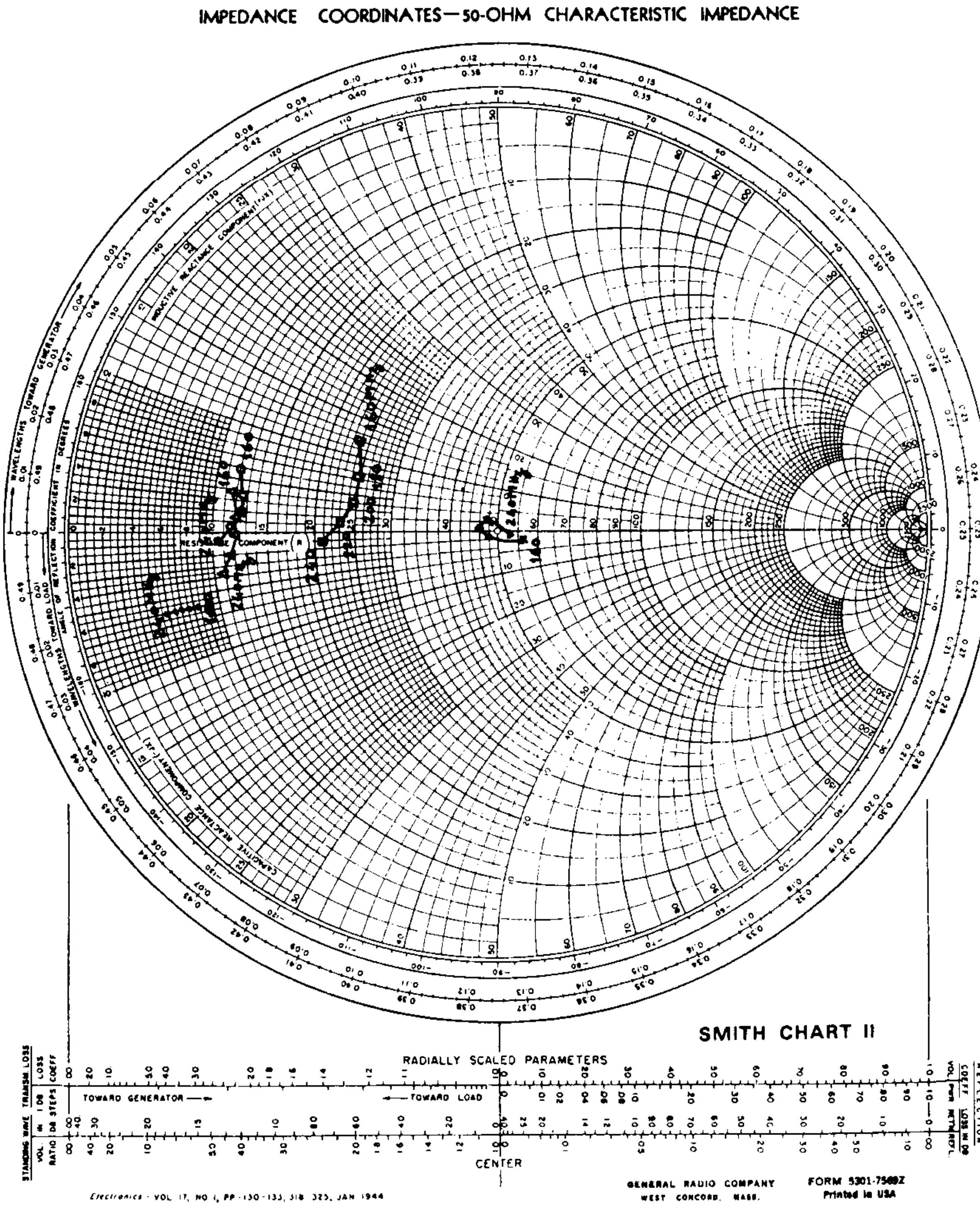


Figure 4B. Output Circuit

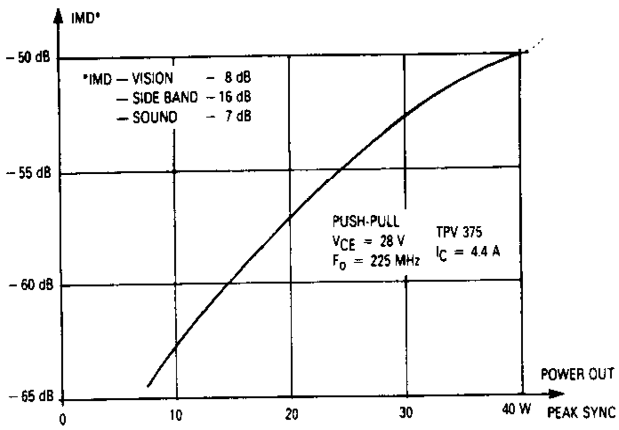


Figure 5. IMD versus Output Power

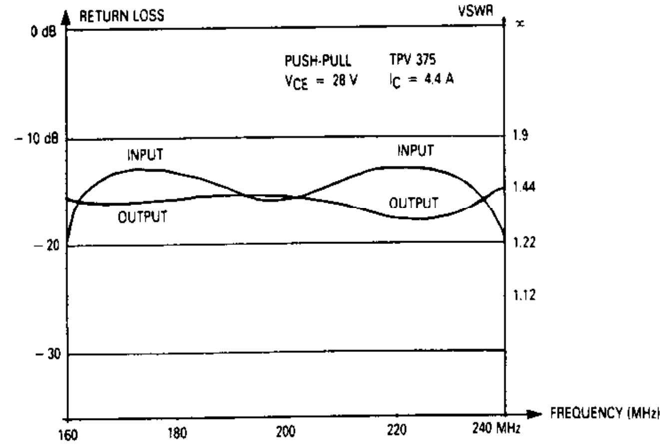


Figure 6. Input and Output Return Loss versus Frequency

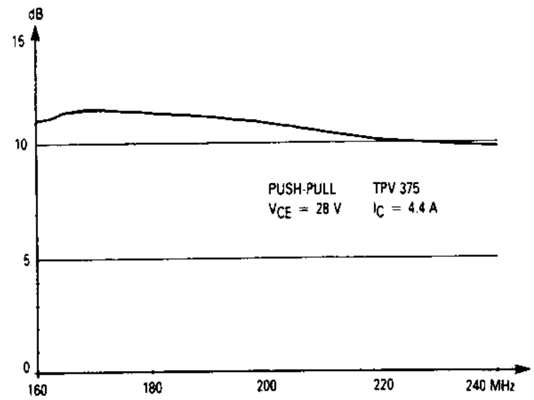
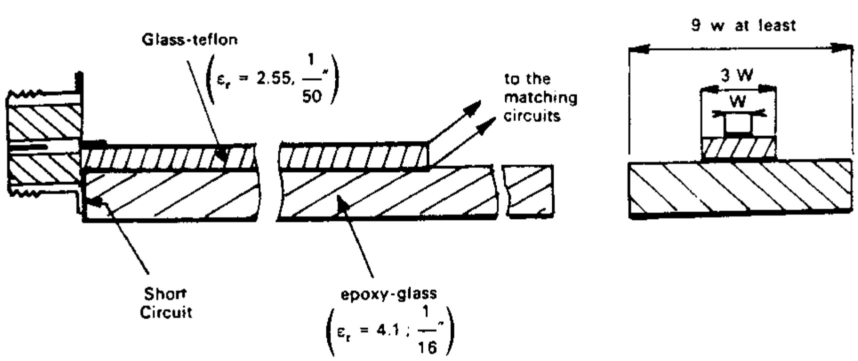
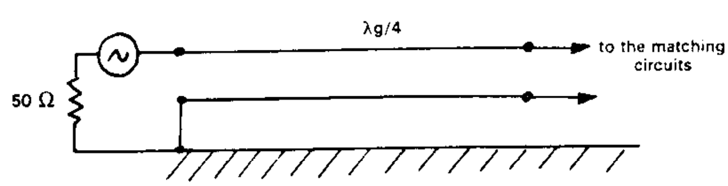


Figure 7. Low Level Gain versus Frequency



a.) Quater Wavelength Balun



b.) Equivalent Circuit

Figure 8.

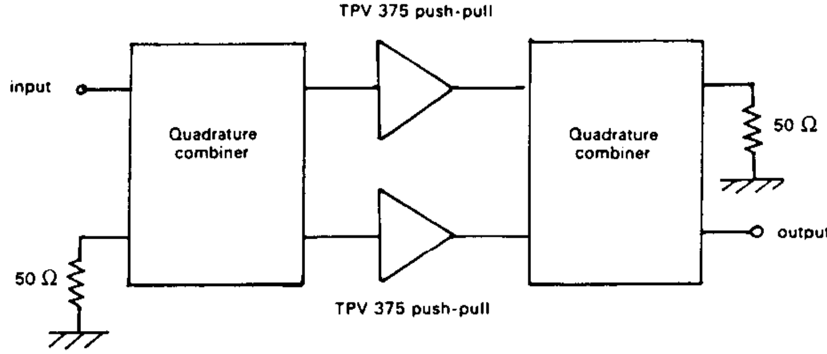
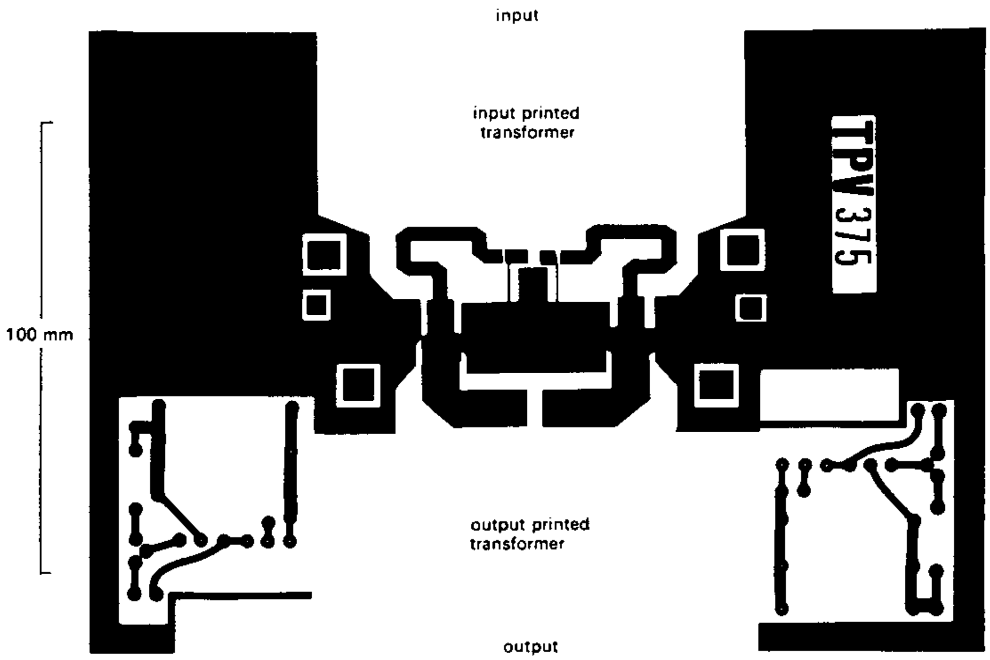
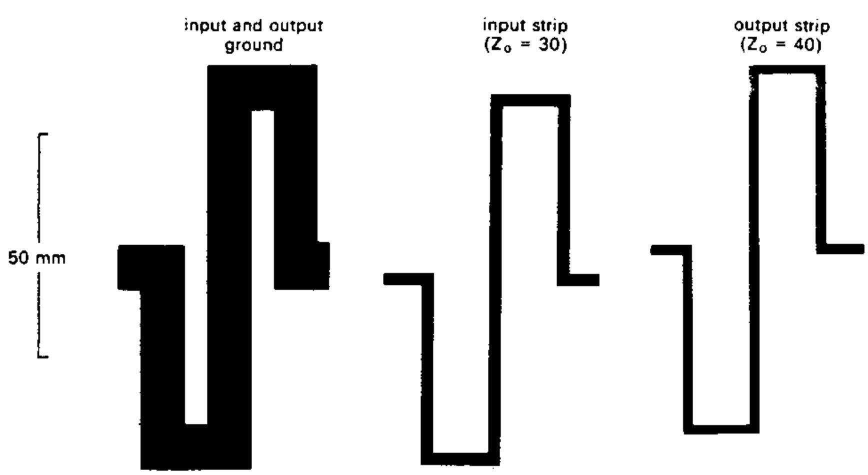


Figure 9. Combined Pair of Push-Pull Amplifiers



Board material : epoxy-glass ; 1/16 inch ; ε_r = 4.1

Figure 10. PC Board Layout (Not to Scale)



Board material : glass teflon ; 1/50 inch ; ε_r = 2.55

Figure 11. PC Board Layout for Input and Output Quater-Wavelength Transformer (Not to Scale)

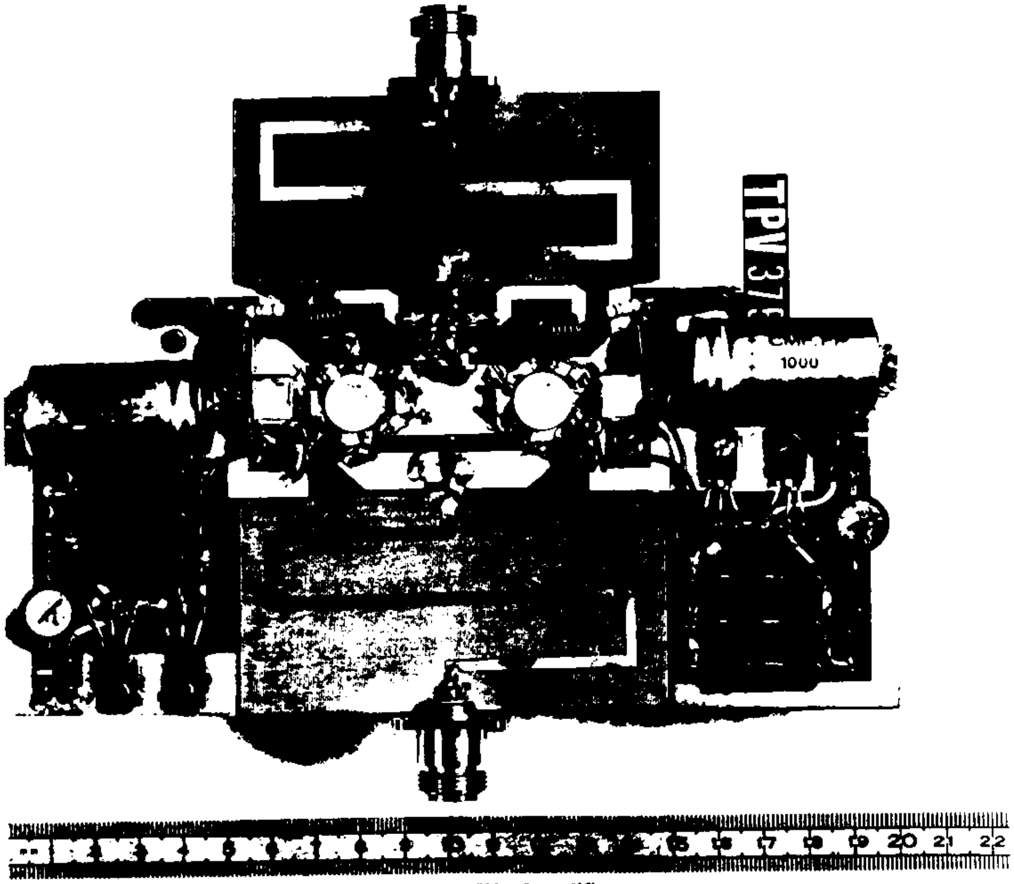
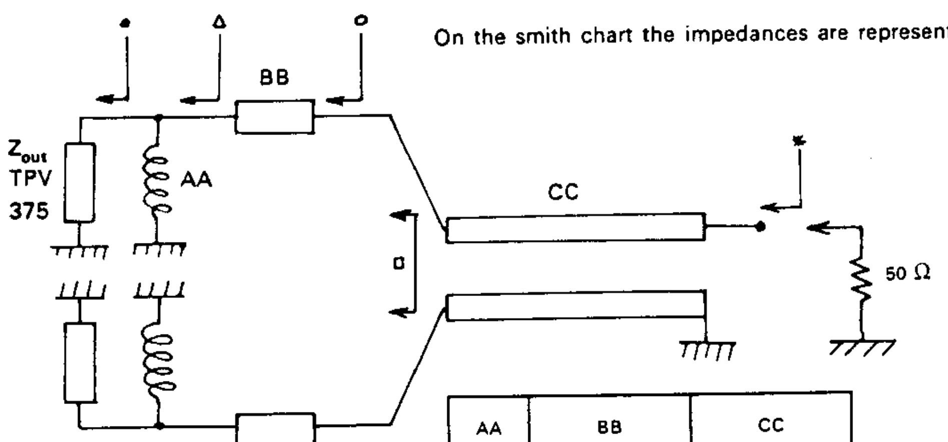


Figure 12. 160–240 MHz Amplifier



On the smith chart the impedances are represented by :

	AA	BB		CC	
	(nH)	Z_0 (Ω)	L* (mm)	Z_0 (Ω)	L* (mm)
Calc. value	11.7	21.6	37.5	33	312.5
Empirical value	53.1	25.0	37.5	40	312.5

* L is given for $\varepsilon_r = 1$

Figure 13. Output Circuit

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